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whence the relative velocity is 13·3 statute miles per second, and the total duration $4\frac{1}{2}$ seconds.

The size of the meteor was described as one-sixth the diameter of the Moon, at Banbury, and also at Brighton, and one-half at Bristol, but doubtless this large size was chiefly due to irradiation.

During the first half of its track, the meteor was like burning magnesium in appearance, then the colour became red, and lastly was vivid green. All along its track fiery ashes fell towards the Earth, and after the extinction of the principal part, a body of dark red sparks continued to fall for a short distance, as seen at Tetbury by Mr. Davis. Lady Portsmouth, driving near Basingstoke, 90 miles from the meteor, and facing west, "was startled by what appeared to be blue or bluish-green lights falling apparently in large flakes into a field on her left. Some seconds after, while the whole country was lighted up as if by the brightest possible lightning, a large red ball was seen travelling with comparative slowness on the right, over a field, into which it appeared to fall." From Waterford the meteor was seen to be double, one part closely following the other. This duplicity is not reported from any other place.

The meteor left little or no streak, and did not detonate, for several of the observers state that they listened for any noise.

The average of all the recorded times is $9^{h}\ 57^{m}$ G.M.T.

In Mr. Greg's List of Meteoric Radiants for 1874, No. 15 is R.A. 143°, N.P.D. 97°, from January 3 to March 16 (?). Such a radiant would be nearly stationary for a long time, as the meteors overtake the Earth obliquely; its duration to March 17 is therefore confirmed.

A curious instance of the inaccuracy with which meteor tracks are sometimes described is that of "J. M. W." in the *Times*, who says that "in London the meteor was two-thirds the size of the Moon *when overhead*." As a matter of fact, it was never within 65° of the zenith of London.

Two Mechanical Solutions of Kepler's Problem.

By Prof. C. Pritchard.

It is unnecessary to dilate upon the boon which would be conferred on observatories and computers, if the tiresomeness of the solution of this problem can be diminished. Every skilful computer has no doubt his own peculiar method, which to him by habit facilitates the work more or less; perhaps that proposed by Dr. de Gasparis in the last Number of the *Monthly Notices* will be among the best. I venture to submit to the Society two mechanical methods of solution, which in the course of less than two minutes landed me just at the point reached in the ex-

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ample given by Dr. de Gasparis above. The principle is as follows; but the description, if full, would occupy more time than the practical working of an actual case. Suppose a lath AB (fig. 1) divided into inches and tenths, and that two *trammels* slide upon it, accurately fitted. Each inch is intended to represent the length of an arc of a circle of one degree, the radius of which, therefore, is 57·296 inches. This subdivision into tenths is equivalent to one hundredth of an inch by estimation, and admitting of no error of that amount, i.e. no error amounting to 36″. The other implement required is a good carpenter's rule (fig 2) with a good hinge, with a line on each of the two laths, diverging from the middle of the hinge as the origin, and each line divided into the line of natural sines OC, OD to one tenth of a degree, and to the same radius as the lath. This implement forms, in fact, what is technically called a *sector*. Suppose the question were: "Having given M, the mean anomaly, $= 15^\circ{\cdot}676$, and the eccentricity $e = {\cdot}5$, required the eccentric anomaly u."

The well-known form is $u = \mathrm{M} + e \sin u$.

Inasmuch as the sine of 30° is one-half of the radius, open the two legs of the jointed rule, or *sector*, until from 30° to 30° spans $\cdot 5 \times \sin 30^\circ$, or one-fourth of 57·296 inches, i.e. 14·324 inches. It follows from the construction that, in the sector thus opened, from 10° to 10° will span $\frac{1}{2} \sin 10^\circ$, and from 20° to 20°, $\frac{1}{2} \sin 20^\circ$ &c., and so on for all corresponding divisions of the two lines of natural sines. The sector being thus prepared, take the divided lath and set one trammel (A) at the mean anomaly 15·68 inches, and let the other trammel (B) be moved backwards and forwards until a division (u) is found on it, such that from A to B will span across the space between the same identical divisions u to u on the opened sector; u° is then the eccentric anomaly sought. In this example u° turns out to be 30° *quam proximè*.

The reading of this description of the *modus operandi* has probably occupied more time than the working of an actual instance when once understood. The truth also of the method is obvious. For, from O to A on the lath is made to equal the mean anomaly, and from A to B, found as above, is $e \sin u$; consequently from O to B, i.e. the reading of B on the divided lath, is $\mathrm{OA} + \mathrm{AB} = \mathrm{M} + e \sin u = u$.

Practically, my own implements are, for convenience, constructed with a radius of 20 inches, and as these land us at once within 1′·5 of the true value of u, it is quite near enough for the application of the differential formula, finally completing the value of u. Of course, if the scales were absolutely divided, and could be so read, the solution above obtained would be strictly accurate. But supposing the reading thus obtained to be u_0, and the correct value $u_0 + \delta u$, then

$$\delta u = \frac{\mathrm{M} + e \sin u_0 - u_0}{1 - e \cos u_0}.$$

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Fig. 3.

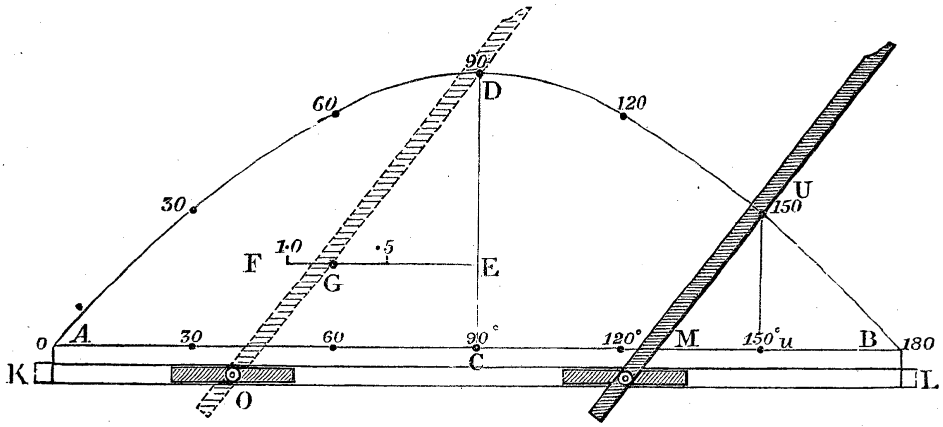


Fig. 4.

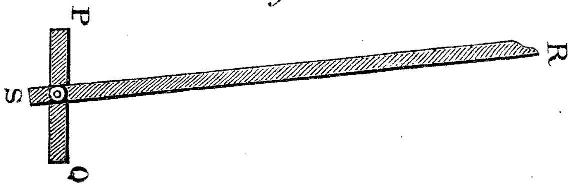


Fig. 1.

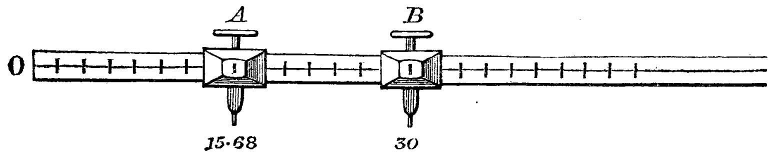
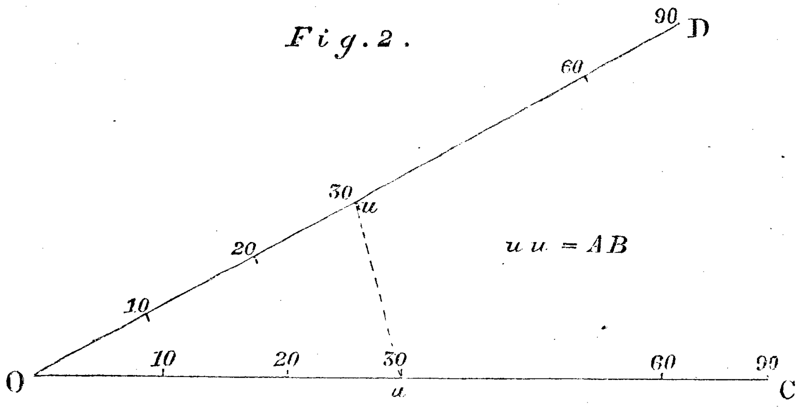


Fig. 2.



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I will merely add that it is obvious that the length of the divided lath may be considerably curtailed in practice by a double *numbering* of the divisions, the upper numbering commencing (say) at 80° and proceeding to 180°, and the lower commencing with 0° and proceeding to 90°.

Other minor conveniences will suggest themselves to any computer of ingenuity, and the author of this paper will be happy to give any further assistance or description required.

Besides the preceding method, I have completed another contrivance, which is, perhaps, equally effective, and even somewhat easier to use, inasmuch as there is nothing *tentative* in its application. The germ of the thought will be found in the *Monthly Notices* a few years back, where Mr. Proctor refers to a method proposed by Prof. Adams, and which he there elaborates at some length, but which practically cannot well be utilised in computations. (See *Monthly Notices*, April 1873.)

The machine as used in the Oxford University Observatory is as follows:—

On a flat board is carefully stretched a sheet of paper, divided into squares of one inch, and subdivided again into squares of twentieths or thirtieths of inches.

This paper (or others like it) is supplied by Messrs. Waterlow, of Birchin Lane, London, and no doubt can be procured elsewhere.

From A to B is 45 inches (fig. 3), divided into 180 equal parts by means of the engraved lines. Each inch represents four degrees.

On this as base is erected the curve of sines so that CD, the sine of 90°, is equal to the radius, i.e. to the length of the arc of $57^{\circ}\cdot296$, or $14\cdot324$ inches. DE is taken = 10 inches, and EF, perpendicular to it, is also 10 inches, divided by the engraved lines into twentieths of an inch. Below AB is a groove, KL, strictly parallel to the base AB. Into this groove is placed the slider PQ (fig. 4) carrying at its middle a thin lath with a perfectly straight bevelled edge, ROS, which, by means of a thumbscrew, moves round O, and can be thereby fixed at any inclination to PQ. The curvilinear part ADB is numbered correspondingly to the base ACD for every 10 degrees, and is capable of being read, by means of the engraved lines and estimation of subdivisions, to 2′ of arc.

The application of this simple implement to an actual example is easy and rapid.

For instance, let the mean anomaly $M = 124^{\circ}\cdot933$, $e = \cdot875$, and let it be required to find the eccentric anomaly U. For this purpose place the slide in the groove, and move the lath round O until the straightedge passes precisely against D and G, where the reading of G on the small scale EF is the eccentricity —here = $8\cdot75$ inches. Then clamp the lath by means of the thumbscrew; and slide it until its edge stands precisely against the mean anomaly M on the base, where the reading is here $124^{\circ}\cdot933$ as near as estimation admits. Then the reading

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U, where the straightedge cuts the line of sines, is the eccentric anomaly sought. In this instance U reads 150° *quam proxime*, but probably not exactly. Whatever the reading is, it can be treated in the usual way as a close approximate solution; and from it exactness to any amount of precision may be obtained by the application of the differential formula above. It will be observed that the only novelty here claimed consists in the application of the slider in the groove, thus obviating any drawing of parallel lines; and in the adaptation of the small scale EF, thus furnishing an immediate means of placing the straightedge at the proper inclination to the base ACB required by the eccentricity e.

This machine admits of home manufacture: and either of the two solves the question of Kepler's Problem with sufficient accuracy for double-star orbits without further computation.

The demonstration is obvious. For

$$\mathrm{M}u = \mathrm{U}u.\cot \mathrm{DGE} = \frac{\mathrm{GE}}{\mathrm{ED}}\cdot \mathrm{U}u = e \sin \mathrm{A}u;$$

hence

$$\mathrm{A}u = \mathrm{AM} + \mathrm{M}u = \mathrm{M} + e \sin \mathrm{A}u.$$

that is

$$e\mathrm{U} = \mathrm{M} + e \sin \mathrm{U}.$$

On the Inequality in the Moon's Longitude discovered by Prof. Newcomb. By E. Neison, Esq.

In my communication to the Society entitled "On the Lunar Perturbations arising from the Planet *Jupiter*" (*Monthly Notices*, xxxvii p. 248), reference was made to a new periodical term in the Moon's Longitude of the form

$$\delta v = -1''\cdot163 \sin\{(2-2m_1-c)\,nt+f-2f_1+\mathrm{A}\},$$

where $(nt+f)$ denotes the mean longitude of the Moon, $(cnt+f-\mathrm{A})$ is the mean anomaly of the Moon, and (m_1nt+f_1) represents the mean longitude of *Jupiter*. Reducing the argument of this term to a form depending on the mean anomaly of the Moon $(=g)$ and a term increasing directly with the time, it becomes

$$\delta v = -1''\cdot163 \sin\{g+20^\circ\cdot85\,(\mathrm{Y}-1855\cdot76)\},$$

or, what is the same thing,

$$\delta v = +1''\cdot163 \sin\{g+20^\circ\cdot85\,(\mathrm{Y}-1864\cdot4)\}.$$

In his communication to the Society, "On a hitherto unnoticed Inequality in the Longitude of the Moon" (*Monthly Notices*, June 1876, p. 358), Prof. Newcomb describes a new empirical term discovered by himself, and which is

$$\delta v = -1''\cdot5 \sin\{g+\mathrm{N}^\circ-90^\circ\},$$